Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

In the Matter of	)	
	)	
Space Exploration Holdings, LLC	)	
	)	
Application for Modification of	)	File No. SAT-MOD-20200417-00037
Authorization for the SpaceX NGSO	)	
Satellite System	)	
	)	

REPLY OF KUIPER SYSTEMS LLC

Julie N. Zoller
Head of Global Regulatory Affairs

Andrew Keisner
Lead Counsel

Mariah Dodson Shuman
Corporate Counsel

Kuiper Systems LLC
410 Terry Avenue N
Seattle, WA 98109

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REPLY OF KUIPER SYSTEMS LLC

Kuiper Systems LLC, a wholly owned subsidiary of Amazon.com Services LLC (collectively, "Amazon"), hereby submits this reply in response to the Consolidated Opposition[1] filed by Space Exploration Holdings, LLC ("SpaceX") opposing Kuiper Systems LLC's Petition to Deny[2] the above-referenced application in which SpaceX seeks to substantially redesign its satellite constellation (the "Third Modification").[3]

I. INTRODUCTION AND SUMMARY.

SpaceX's Third Modification should be denied due to its significant deleterious effects on both space safety and the interference environment of non-geostationary satellite orbit ("NGSO") fixed-satellite service ("FSS") constellations, such as the Kuiper System.[4] SpaceX characterizes its Third Modification as simply building on its first two modifications and the "success of the

[1] Consolidated Opposition to Petitions and Response to Comments of Space Exploration Holdings, LLC, IBFS File No. SAT-MOD-20200417-00037 (filed July 27, 2020) ("*SpaceX Opposition*").
[2] Petition to Deny and Comments of Kuiper Systems LLC, IBFS File No. SAT-MOD-20200417-00037, (filed July 13, 2020) ("*Amazon Petition*").
[3] Application of Space Exploration Holdings, LLC for Modification of Authorization for the SpaceX NGSO Satellite System, IBFS File No. SAT-MOD-20200417-00037 (filed Apr. 17, 2020) ("*Third Modification*").
[4] *See Kuiper Systems LLC*, Order and Authorization, FCC 20-102, IBFS File No. SAT-LOA-20190704-00057, (rel. July 30, 2020) ("*Kuiper System Grant*").

deployment of its first 362 satellites,"[5] but close inspection shows this is not the case. The Third Modification extends further than the scope of the first two modifications and has a more damaging impact. The First Modification enabled SpaceX to reduce the number of satellites in its constellation from 4,425 to 4,409; operate 1,584 satellites at 550 km rather than 1,150 km; and make related changes.[6] The Second Modification redistributed the satellites in the 550 km orbital shell among different orbital planes.[7] Both were modifications to the orbital configuration of the constellation, not of the satellites making up that constellation.

The Third Modification proposes to change not only the orbital configuration of the constellation, which it does more significantly than did the first two modifications, but the design of the satellites that would occupy those orbits. Specifically, SpaceX proposes to lower the Ka-band satellite antenna gain (consequently widening the beam width), lower the elevation angle by 15 degrees, and double the number of satellites linking to each of its gateways. SpaceX proposes to apply these changes to the 2,824 satellites it is seeking to relocate *and* to the satellites in the 550 km orbital shell—in other words, its entire constellation. This is not a benign reconfiguration of its authorized system; this redesign constitutes a broad expansion of the operational envelope of the SpaceX system. This expansion would have a much more significant effect on other NGSO FSS operators than did the first two modifications and would undermine the Commission's policy goals underlying its use of NGSO FSS processing rounds.[8]

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[5] *Third Modification*, at Attachment A, 2.

[6] *See* Application of Space Exploration Holdings, LLC for Modification of Authorization for the SpaceX NGSO Satellite System, SAT-MOD-20181108-00083 (filed Nov. 8, 2018) ("*First Modification*").

[7] *See* Application of Space Exploration Holdings, LLC for Modification of Authorization for the SpaceX NGSO Satellite System, IBFS File No. SAT-MOD-20190830-00087 (filed Aug. 30, 2019) ("*Second Modification*").

[8] *See Update to Parts 2 and 25 Concerning Non-Geostationary, Fixed-Satellite Service Systems and Related Matters*, Report and Order and Further Notice of Proposed Rulemaking, 32 FCC Rcd

In its Petition to Deny, Amazon provided an in-depth analysis of the negative space safety effects that would result from the Third Modification's proposal to lower 2,824 satellites by as much as 765 km, particularly given SpaceX's wide orbital variance of +/- 30 km. Amazon also proposed solutions to this problem, including requiring SpaceX to limit its orbital variance or change the altitude of its new orbits so as not to overlap with another large constellation.[9] In addition to space safety concerns, Amazon provided an analysis of the Third Modification's significant effect on the interference environment, and noted that this alone was sufficient under Commission precedent to include the SpaceX constellation in the NGSO FSS Processing Round initiated on March 24, 2020 (the "2020 Processing Round").[10]

Despite other commenters providing similar analyses, SpaceX's Opposition failed to address the critical issues raised. Instead, the Opposition deflected concerns regarding space safety (including by providing irrelevant analysis regarding the volume of orbital space in comparison to

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7809, ¶ 61 (2017) ("*NGSO FSS Order*") ("The purpose of the recent processing rounds was to establish a sharing environment among NGSO systems, to provide a measure of certainty in lieu of adopting an open-ended requirement to accommodate all future applicants."). *See also Space Exploration Holdings, LLC*, Order and Authorization, IBFS File No. SAT-MOD-20181108-00083, ¶ 9 (Apr. 26, 2019) ("*First Modification Authorization*") ("[T]he Commission's processing round procedure . . . is designed to establish the interference environment in which participants in the processing round could operate their systems. If a modification would worsen the interference environment, that would be a strong indication that grant of the modification would not be in the public interest.").

[9] This requirement would reflect the Commission's expectation that operators voluntarily avoid or mitigate overlap. *See Mitigation of Orbital Debris in the New Space Age*, Report and Order and Further Notice of Proposed Rulemaking, 35 FCC Rcd 4156, ¶ 47 (April 23, 2020) ("*Mitigation of Orbital Debris Report and Order and FNPRM*") ("As a practical matter, in cases where two planned systems propose use of the same shell, coordination typically results in one or both systems adjusting planned orbital altitudes, so that the constellations are separated, rather than in the operators coordinating their operations at the same or overlapping altitude ranges.").

[10] *See Satellite Policy Branch Information, Cut-Off Established for Additional NGSO FSS Applications or Petitions for Operations in the 10.7-12.7 GHz, 12.75-13.25 GHz, 13.8-14.5 GHz, 17.7-18.6 GHz, 18.8-20.2 GHz, and 27.5-30 GHz Bands*, Public Notice, Report No. SPB-279, DA 20-325 (Mar. 24, 2020).

the volume of satellites), and failed to commit to maintaining a responsible orbital tolerance. Additionally, SpaceX declined to clarify ambiguous data regarding the poor reliability of its satellites, which only exacerbates the risks to space safety. The Opposition also provided an inaccurate assessment of the interference analyses submitted by Amazon and others. Those analyses show that the Third Modification will significantly worsen the interference environment, a fact which prevents grant under the *Teledesic* standard and should lead the Commission to include the Third Modification in a later processing round under existing precedent. Thus, even if the substantial space safety challenges warranting denial can be overcome, the Commission should nonetheless include the entire SpaceX system in the 2020 Processing Round to protect the public interest and promote regulatory certainty for current and future NGSO FSS operators.

II. SPACEX HAS NOT RESOLVED THE SIGNIFICANT SPACE SAFETY ISSUES RAISED BY COMMENTERS.

A. SpaceX has failed to remedy the safety concerns implicated by orbital overlap between large NGSO constellations.

The Commission has repeatedly recognized that space safety is an important priority in carrying out its statutory mission to "encourag[e] 'the larger and more effective use of radio in the public interest.'"[11] Specifically, "orbital debris and related mitigation issues are relevant in determining whether the public interest would be served by authorization of any particular satellite-based communications system, or by any particular practice or operating procedure of such satellite systems."[12] Amazon and other commenters in this proceeding have likewise emphasized the importance of space safety in analyzing the Third Modification. SpaceX's

[11] *Mitigation of Orbital Debris* Report and Order and FNPRM, at ¶ 15 (quoting 47 U.S.C. § 303(g)).
[12] *Id*.

Opposition has not adequately addressed the safety concerns commenters identified; thus, denial of the application is warranted.[13]

The orbital overlap created by SpaceX's Third Modification is far more significant than that created by its First Modification[14] and creates greater risk of conjunction events.[15] Instead of addressing this harm directly, SpaceX emphasizes the safety effects of the Third Modification, saying that it "would make SpaceX's system safer in nearly every respect."[16] However, SpaceX disregards the increased orbital overlap with and collision risk to other systems. The significant increase in conjunction risk to the Kuiper System is unnecessary in order to garner the safety gain from SpaceX's lower orbital altitude.

SpaceX's Opposition does not effectively refute the space safety analyses submitted by Amazon, Kepler, SES/O3b, Spire, and Viasat, all of whom identify the Third Modification's orbital overlap with the Kuiper System and others as creating serious risk of conjunction events.[17]

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[13] *SpaceX Opposition*.

[14] *See Amazon Petition*, at 8-10 (graphically demonstrating increased orbital overlap between the Starlink system and the Kuiper System and analyzing "more than an order of magnitude increase" in potential expected daily conjunction events).

[15] In its Opposition, SpaceX notes that it "is authorized to operate its NGSO system at altitudes similar to those authorized for Telesat and OneWeb," and thus that "some degree of overlap . . . is nothing new." *SpaceX Opposition*, at 8. The Commission has granted authority for OneWeb to deploy 720 satellites to an orbital altitude of 1200 km +/- 38 km, *see WorldVu Satellites Limited*, Order and Declaratory Ruling, 32 FCC Rcd 5366, ¶ 2 (2017), and for Telesat to deploy 72 satellites at 1000 km +/- 300 meters and 45 satellites at 1248 km +/- 300 meters, *see Telesat Canada*, Order and Declaratory Ruling, 32 FCC Rcd 9663, ¶ 2 (2017); Letter from Elisabeth Neasmith, Director, Spectrum Management and Development, Telesat, to Jose P. Albuquerque, Chief, Int'l Bureau, FCC, at 4 (filed Apr. 14, 2017) ("*Telesat Letter*") ("The space station orbit parameters will be maintained as follows: Apogee or Perigee Altitude: ±300 meters."). SpaceX's orbital shell at 1275 km, containing 375 satellites, would overlap only with Telesat's 45 satellites deployed at 1248 km. This is in contrast to 1240 of SpaceX's satellites overlapping with 784 satellites in the Kuiper System after the Third Modification.

[16] *SpaceX Opposition*, at ii.

[17] Petition to Deny of Kepler Communications Inc., IBFS File No. SAT-MOD-20200417-00037 (filed July 13, 2020) ("*Kepler Petition*"); Petition to Deny or Defer of SES Americom, Inc. and O3b Limited, IBFS File No. SAT-MOD-20200417-00037 (filed July 13, 2020) ("*SES/O3b*

Spire, whose constellation would also be subject to overlap given SpaceX's wide +/- 30 km orbital variance, explains that it may need to "execute more differential draft maneuvers in response to potential conjunction events."[18] Viasat agrees that "significant overlap will exist with both the Kuiper system and the Kepler system, and many of the cubesat systems,"[19] and that this modification "poses a substantially increased risk of collision with other satellites in the same or similar orbital altitudes."[20]

SpaceX neglected to resolve these concerns, in spite of the fact that Amazon proposed two different solutions that would eliminate the overlap with the Kuiper System and allow SpaceX to modify its system in a more responsible manner.[21] Indeed, the SpaceX Opposition did not respond to Amazon's proposals to maintain stricter orbital tolerances or limit the SpaceX nominal altitude to no higher than 550 km.[22] Instead, SpaceX "wonders whether [] competitors would approve of SpaceX operating at any altitude."[23] Amazon designed the Kuiper System with altitudes of 590 km, 610 km, and 630 km and an orbital tolerance of only +/- 9 km so that it would avoid physical overlap with other large constellations, including the previously modified SpaceX system with an orbital shell at 550 km and its wide +/- 30 km orbital variance.[24] The Kuiper System design will

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Petition"); Comments of Spire Global, Inc., IBFS File No. SAT-MOD-20200417-00037 (filed July 13, 2020); ("*Spire Comments*"); Petition to Deny or Defer of Viasat, Inc., IBFS File No. SAT-MOD-20200417-00037 (filed July 13, 2020) ("*Viasat Petition*").

[18] *Spire Comments*, at 2.

[19] *Viasat Petition*, at 11.

[20] *Id.* at 10.

[21] *Amazon Petition*, at 12-13.

[22] *Id.*

[23] *SpaceX Opposition*, at 9. SpaceX references the Kuiper System's overlap with Swarm, Spire, and Planet Labs, *id.* at 12, but none of these systems creates collision risk that is at all similar to what SpaceX proposes in the Third Modification.

[24] At the time of Amazon's filing, Swarm had not applied to exceed 550 km, *see Swarm Technologies, Inc.*, Memorandum Opinion, Order, and Authorization, 34 FCC Rcd 9469 (2019); Spire was licensed to operate up to 175 satellites simultaneously, *see Spire Global – Grant In Part, Defer in Part*, Stamp Grant, IBFS File Nos. SAT-LOA-20151123-00078, SAT-AMD-20180102-

ensure rapid post-mission disposal *and* achieve orbital separation. SpaceX should select its orbits with these same goals in mind.

In response to criticism regarding its wide orbital variance, SpaceX notes that a +/- 30 km tolerance provides it flexibility to perform collision avoidance maneuvers or relocate satellites;[25] however, maneuvers implementing meters (not kilometers) of altitude change are sufficient to achieve orbital maintenance and debris avoidance. Additionally, despite SpaceX's claim that it "will conduct active maneuvers to avoid collisions with both debris and other spacecraft,"[26] it has specifically stated that doing so should not be a license condition for its modified system, even with respect to non-propulsive systems.[27]

Further, SpaceX seeks to deflect any collision concerns by noting that Amazon's conjunction event analysis "assumed a [sic] 'a particular orbital configuration' for the SpaceX satellites."[28] While SpaceX claims that such a configuration is "not a valid assumption," it is within the system configuration proposed in the Third Modification. SpaceX stops short of committing not to use such a configuration. Instead, SpaceX states that "there will be relatively little variation from nominal altitude and overlaps involving SpaceX satellites assigned to planes in different altitudes or with other NGSO systems assigned to different altitudes will be rare."[29] If that is the case, it should not be a burden for SpaceX to maintain a tighter orbital tolerance. Given

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00001, at ¶ 3 (Nov. 28, 2018); *Spire Global – Grant In Part, Defer in Part*, Stamp Grant, IBFS File No. SAT-PDR-20190321-00018, at ¶ 3 (Oct. 7, 2019); and Planet Labs was not authorized to operate more than 120 satellites with an apogee altitude above 550 km, *see Planet Labs Inc. – Grant*, IBFS File No. SAT-MOD-20170713-00103, at ¶¶ 3-4 (July 19, 2018).

[25] *SpaceX Opposition*, at 10 (quoting *Amazon Petition*, at 10 n.28).

[26] *Id.* at 14.

[27] *Third Modification*, at 11 ("[A]s an operational matter, SpaceX's propulsive capabilities enable it to avoid non-propulsive systems unilaterally. Yet these types of voluntary steps would be a poor basis for license conditions.").

[28] *SpaceX Opposition*, at 10.

[29] *Id.*

SpaceX's "advanced propulsion capabilities"[30] and intention to operate with little variation from nominal altitude, maintaining an orbital tolerance that prevents SpaceX from overlapping with the Kuiper System would be neither an undue hardship nor a limitation on the range of broadband service SpaceX intends to provide. The Commission should either require SpaceX to control apogee and perigee strictly enough to preclude orbital overlap with the Kuiper System or limit SpaceX's nominal altitude to no higher than 550 km.

B. The volume of spacecraft as compared to the total volume of orbital space is not an appropriate measure of collision risk.

OneWeb and Viasat, in addition to Amazon, provided analyses showing the increase in collision risk created by the Third Modification. Amazon also provided a detailed analysis of the potential for a nearly 16-fold increase in daily conjunction events for the Kuiper System,[31] and noted that SpaceX satellite reliability issues could compound this problem.[32] Rather than respond directly to these increased measures of risk to space safety, SpaceX stated that commenters failed to "consider[] the total volume of SpaceX's satellites compared to the volume of space in which they will operate."[33] In other words, SpaceX tells the Commission to ignore legitimate space safety concerns because, in its overly simplistic view, satellites are small and space is large. The notion that the risk of collision between two satellites is small simply because space is large is a fallacy. Satellites are not fixed in space such that their paths never cross. As Amazon has demonstrated, the configuration proposed in the Third Modification could increase the daily incremental close approaches between Kuiper System satellites and SpaceX satellites by more than an order of magnitude.[34]

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[30] *Id.* at 14.
[31] *Amazon Petition*, at 10.
[32] *Id.* at 12.
[33] *SpaceX Opposition*, at 6.
[34] *See Amazon Petition*, at 10.

Indeed, SpaceX's own close approach with the European Space Agency (ESA) Aeolus satellite belies its reliance on volume to mitigate risk. SpaceX's description of the incident in its Opposition states that "SpaceX did not learn of ESA's correspondence," but also states that if it had, it would have "shar[ed] details and health information from its state-of-the-art autonomous conjunction avoidance system."[35] This does not establish whether SpaceX would have maneuvered, what SpaceX's maneuvering risk threshold was (and will be in similar situations in the future), or whether the SpaceX satellite involved was functional and capable of maneuvering.[36] Especially considering the increased number of conjunction events created by the Third Modification, space safety concerns cannot be dismissed on the premise that "space is large;" action should be taken to mitigate those concerns.

C. SpaceX has not adequately resolved ambiguous statements regarding the maneuverability status of its space stations.

As several commenters including Viasat[37] and OneWeb[38] noted, the space safety concerns posed by the Third Modification are intensified by the ambiguity of SpaceX's statements regarding the status of its satellites. SpaceX claims to be transparent in its operations because it shares "information regarding initial deployment, ephemeris, and planned maneuvers with the 18th Space

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[35] *Id.* at 17.

[36] Historical TLE data from space-track.org indicates that the SpaceX satellite that was involved in the close approach appears to have deorbited since then. Space-Track, http://space-track.org/ (last visited August 6, 2020) ("*Space-Track Data*"). The Commission should inquire as to SpaceX's maneuver threshold to assist operators in predicting SpaceX's collision avoidance behavior.

[37] *See Viasat Petition*, at 15 ("SpaceX has reported an experiential value of 1.9% for its v1.0 satellites (9 of 478 failed). However, these failures occurred over an average time of less than 5 months after being launched. If the SpaceX satellites continue to fail at 1.9% per 5 months once above injection orbit, then the failure rate per satellite over its 5-year lifetime would be 22.8%. While this may seem like a high value, it is not unreasonable considering that SpaceX reported a 1.9% failure rate (9 of 478 failed) just 5 weeks after reporting a 1.7% failure rate (6 of 360).").

[38] *See* Comments of OneWeb, IBFS File No. SAT-MOD-20200417-00037, at 6 (filed July 13, 2020).

Control Squadron" and also provides "all of its ephemeris data to other NGSO operators via space-track.org and other public means."[39] However, "transparency" is only useful when the information being shared is valid, timely, and consistent—a standard that SpaceX's data does not appear to meet. For example, in previous FCC filings, SpaceX first claimed that 12 satellites "lost maneuver capabilities above injection altitude" across its entire constellation.[40] One month later, it amended this to state that 9 "satellites with diminished maneuverability [were] slotted for de-orbit" across the v1.0 portion (those launched after the first tranche) of its constellation.[41] This data is shown below in Figure 1.

Figure 1: Starlink Failure Rates

	May 15, 2020 Filing[42]	**June 23, 2020 Filing[43]**
V0.9	6 "lost maneuver capabilities above injection altitude"	*Not Provided
V1.0	6 "lost maneuver capabilities above injection altitude"	9 "with diminished maneuverability slotted for de-orbit"
Constellation Total	12	15 (*assuming no further V0.9 satellites with diminished maneuver capabilities since the May 15, 2020 filing)

As of June 23, 2020, publicly available historical TLE data from space-track.org suggests that more than 15 satellites across the Starlink constellation (v0.9s and v1.0s) are not maneuverable, and that number appears to be increasing, raising concerns about reliability of SpaceX's satellites.[44] This contradicts what SpaceX filed with the FCC.

[39] *SpaceX Opposition*, at 14.
[40] *See* Response to FCC Information Request of Space Exploration Holdings, LLC, IBFS File No. SAT-MOD-20200417-00037, at 4 (filed May 15, 2020) ("*SpaceX Response*").
[41] Letter from William M. Wiltshire, Counsel to SpaceX, to Marlene H. Dortch, Secretary, FCC, at 1-2 (June 23, 2020) ("*2020 Annual Report*").
[42] *SpaceX Response*, at 5, Table 2.
[43] *2020 Annual Report*, at 2, Table 1.
[44] *Space-Track Data*.

Moreover, these discrepancies make it difficult to assess the validity of the data that SpaceX is providing to operators, the 18th Space Control Squadron, and the FCC. They likewise make it challenging to determine the failure rate of the SpaceX constellation, the supposed "success" of which is the basis for SpaceX's proposed system redesign.[45] Amazon urges the FCC to require SpaceX to address these discrepancies, as well as identify the NORAD catalog ID numbers of SpaceX satellites that are deorbited or not maneuverable.

Unless all of the space safety concerns enumerated above are resolved, the Third Modification should be denied.

III. THE THIRD MODIFICATION HAS A SIGNIFICANT IMPACT ON THE INTERFERENCE ENVIRONMENT THAT WARRANTS INCLUSION IN THE 2020 PROCESSING ROUND.

A. SpaceX's redesigned constellation should be included in the 2020 Processing Round.

SpaceX's modification application (filed during the window for the 2020 Processing Round) significantly impacts the NGSO FSS interference environment for all systems in the 2016 and 2020 Processing Rounds. These significant interference impacts justify including the redesigned constellation in the 2020 Processing Round if the space safety concerns warranting denial can be overcome.

Kepler,[46] SES/O3b,[47] and Viasat[48] requested that the FCC deny the Third Modification based in part on its significant impact to the interference environment. In addition, SES/O3b joined

[45] SpaceX argues that the Third Modification "proposes to build on the success of its earlier modifications," *Third Modification*, at 1, and is "based on the success of the deployment of its first 362 satellites," *id.* at Attachment A, 2.

[46] *Kepler Petition*, at 1 ("[T]he Modification as proposed will significantly increase the overall interference environment for some systems, including Kepler's.").

[47] *SES/O3b Petition*, at 4 ("Here, the substantial worsening of the interference environment for NGSO and GSO systems requires the Commission to deny the Application.").

[48] *Viasat Petition*, at 37 ("[T]he proposed SpaceX modification presents significant risks of interference into GSO networks and NGSO systems that SpaceX has not addressed or mitigated.").

with Amazon to request that the Third Modification be considered as part of the 2020 Processing Round in the event that concerns requiring denial are resolved.[49] Interference concerns are at the heart of the *Teledesic* standard, which states that a modification should be granted only if "it 'does not present any significant interference problems and is otherwise consistent with Commission policies.'"[50] Indeed, when it granted SpaceX's First Modification, the Commission emphasized that "[i]f a modification would worsen the interference environment, that would be a strong indication that grant of the modification would not be in the public interest."[51] The Third Modification presents substantial interference problems that affect at least four other licensed satellite systems,[52] all of which were designed before SpaceX filed the instant application.

The design and operation of one system necessarily affects the design and operation (or proposed operation) of other systems, particularly in a case such as this where the modified system bears no resemblance to the system as originally authorized. Thus, the processing round framework that establishes "the need to protect existing expectations and investments and provide for additional entry"[53] counsels doubly to place the entire modified SpaceX constellation in the 2020 Processing Round. Doing so would both "protect existing expectations and investments"

[49] *SES/O3b Petition*, at 4 ("At the very least, the breadth of the changes proposed in the Application and the massive increase in interference to O3b require treating the reconfigured SpaceX system as a newly filed request, ineligible for continued inclusion in the Ku/Ka-band NGSO processing round that closed in November of 2016.").
[50] *Third Modification*, at 9 (quoting *Teledesic LLC*, Order and Authorization, 14 FCC Rcd 2261, ¶ 5 (1999) ("*Teledesic*")).
[51] *First Modification Authorization*, at ¶ 9.
[52] *See Amazon Petition*, at 18-19, Figs. 6, 7 (analysis of in-line interference events under the Third Modification to the Kuiper System, O3b, OneWeb, and Telesat).
[53] *NGSO FSS Order*, at ¶ 61.

that have been made based on the interference environment created under the previous processing round and provide for competitive entry by additional systems such as the Kuiper System.[54]

SpaceX has petitioned the Commission to revise its rules to require systems in later processing rounds to demonstrate that they protect systems in earlier processing rounds as a substitute for coordination.[55] SpaceX appears to expect such protection to be required regardless of the modifications earlier rounders make, including those that significantly alter the interference environment. For example, here, SpaceX attempts to isolate Amazon due to the fact that Amazon's now licensed system was pending when SpaceX filed its Third Modification application.[56] However, the Kuiper System was designed based on the pre-existing interference environment as set forth in previously filed NGSO FSS applications. SpaceX had public knowledge of the Kuiper System's design, as well as the designs of other NGSO FSS systems, when it redesigned its system as reflected in the Third Modification.

Requiring SpaceX's redesign to be considered as part of the 2020 Processing Round would not cause SpaceX any undue hardship. The magnitude of SpaceX's proposed changes to its constellation and satellite design means that the Third Modification creates a new operating environment. Thus, considering the effects of such an environment in the context of a new processing round would not impede SpaceX's operation. Indeed, SpaceX "has made no showing at all that it could not provide robust consumer broadband service if it were to participate in a

[54] *Kuiper System Grant*, at ¶ 3 ("*Kuiper System Grant*") ("We conclude that grant of Kuiper's application would advance the public interest by authorizing a system designed to increase the availability of high-speed broadband service to consumers, government, and businesses.").
[55] *See* Revision of Section 25.261 of the Commission's Rules to Increase Certainty in Spectrum Sharing Obligations Among Non-Geostationary Orbit Fixed-Satellite Service Systems, Petition for Rulemaking, RM-11855, 1 (filed Apr. 30, 2020).
[56] *See SpaceX Opposition*, at 21.

second processing round."[57] Granting the Third Modification as proposed, on the other hand, would subject other NGSO FSS licensees in all processing rounds to significantly increased interference and an uncertain operating environment and unfairly exempt SpaceX from the 2020 Processing Round.

In its comments on OneWeb's modification application, SpaceX itself recognized that "to best serve the public interest, the Commission should heed its existing position that license modifications that add potential interference are to be considered in new NGSO processing rounds. This approach was designed to provide certainty to all NGSO applicants in a given processing round by ensuring these modifications are governed by established principles and common parameters, rather than a cascade of change upon change."[58] In reality, the certainty that SpaceX acknowledges for those in a "given processing round" is also necessary for those in later rounds because they, too, rely on the stability of earlier round licenses, and the existing interference environment when designing their systems. Including the modified SpaceX constellation in the 2020 Processing Round would prevent a "cascade of change" resulting from the cumulative effects of the present redesign together with SpaceX's first two modifications. Doing so would also reinforce regulatory certainty and encourage NGSO FSS operators to submit applications that are actually representative of their operational plans.

[57] Reply of Space Exploration Holdings, LLC, IBFS File No. SAT-LOA-20190704-00057, at 19 (filed Nov. 25, 2019).
[58] Comments of Space Exploration Holdings, LLC, IBFS File No. SAT-MOD-20180319-00022, at ii (filed July 30, 2018).

B. The Third Modification has a significant impact on the interference environment.

1. Amazon has demonstrated the significant impact of the Third Modification.

Amazon's Petition included a demonstration of increased interference between Kuiper System gateway links and SpaceX Ka-band links in the Third Modification due to the increase in (1) frequency and duration of in-line interference events, and (2) the statistical distribution of interference-to-noise (I/N) into both systems. Amazon also showed that this increase in interference would impact the Kuiper System's own satellite availability. SpaceX concedes that the Third Modification's proposed lower altitudes render its satellites more susceptible to higher I/N levels in the uplink direction, and that its reduced power flux-density (PFD) renders its gateways more susceptible to interference in the downlink direction.[59] However, SpaceX has not acknowledged the full effect of the Third Modification on the NGSO FSS interference environment.

The reduction in orbital altitude proposed in the Third Modification is not the only cause of the significant increase in interference that NGSO FSS systems will experience. Rather, the increase in interference is caused by a combination of the reduction in orbital altitude, the reduced minimum elevation, the change in satellite beam contours, and the doubling of active satellites at each earth station location. The proposed changes are not a benign reconfiguration of SpaceX's authorized system; they constitute a broad expansion of the operational envelope of the system. Whether viewed individually or in combination with the First and Second Modifications, the Third

[59] *See SpaceX Opposition,* at 23 ("SpaceX concedes that its satellites operating at the lower power and lower altitudes proposed in the modification will be somewhat more susceptible to uplink interference from earth stations communicating with other NGSO systems."). *See also id.* at 25 ("As OneWeb notes, SpaceX proposes to reduce the PFD levels for its Ka-band downlinks by 7 dB. This could make these transmissions to gateways more susceptible to interference.").

Modification proposes a SpaceX NGSO FSS constellation that hardly resembles the original constellation SpaceX filed for years ago.

Further, as discussed below, the increase in SpaceX's beam footprint size as a result of its proposed change to the satellite antennas would cause higher levels of interference to and from other NGSO FSS systems. Due to the broad impact of the Third Modification, and the significant interference effects that it has on other NGSO FSS systems, the reconfigured SpaceX system should be included in the 2020 Processing Round to promote the public interest under the *Teledesic* standard and support the Commission's processing round policy.

2. SpaceX seeks to redesign its satellite antennas and widen its beam footprints, which undermines earth station separation as an interference mitigation technique.

SpaceX proposes a significant change to its Ka-band gateway beam design that appreciably worsens interference to other Ka-band NGSO FSS systems in the downlink direction, and increases SpaceX's susceptibility to interference from other Ka-band NGSO FSS systems in the uplink direction. Specifically, SpaceX proposes to modify its satellite beam parameters and significantly expand its satellite beam contour area. This would prevent the effective use of earth station separation to mitigate interference, render SpaceX's response to Amazon's interference analysis ineffective, and reinforce the significant increase in interference that would result from the Third Modification. In its Original Application, First Modification, and Second Modification, SpaceX's Ka-band satellite beam peak gain was 41 dBi in both the receive and transmit directions.[60] The SpaceX Ka-band satellite beams in these earlier applications and modifications

[60] *See* Application of Space Exploration Holdings, LLC for Approval for Orbital Deployment and Operating Authority for the SpaceX NGSO Satellite System, SAT-LOA-20161115-00118, at Schedule S, 219-227, 229-245 (filed Nov. 15, 2016) ("*Original Application*"); *First Modification*, at Schedule S, 11-22, 33-50; *Second Modification*, at Schedule S, 9-20, 31-48.

represented phased-array antennas on the spacecraft.[61] In the Third Modification, the Ka-band satellite beams have a receive peak gain of 38.5 dBi and a transmit peak gain of 34.5 dBi.[62] These beams represent parabolic-like antennas on the spacecraft, as evidenced by (a) the contours submitted as part of the Third Modification's Schedule S, and (b) SpaceX's declaration that the receive G/T of its Ka-band satellite beams will now remain constant at all pointing directions.[63] Figure 2 shows a summary of how the SpaceX Ka-band satellite beam parameters have been modified in the Third Modification.

Figure 2: SpaceX Ka-band Satellite Beam Parameters

	Unit	**Original Application, First Modification, and Second Modification**	**Third Modification**
Beam Type		Phased Array	Parabolic
Peak Gain (Tx)	dBi	41[64]	34.5[65]
Peak Gain (Rx)	dBi	41[66]	38.5[67]
Peak G/T (Rx)	dBK	13.7[68]	11.5[69]

[61] *See Original Application*, at Attachment A, 13 ("As with Ku-band user beams, the shape of the Ka-band gateway beam becomes elliptical as it is steered away from the boresight as a consequence of the phased array technology employed."). *See also First Modification*, at Attachment A, 9 ("For receiving beams, the antenna gain drops slightly as the beam slants away from nadir. As a result, the maximum G/T (13.7 dB/K) occurs at nadir, while the minimum G/T (11.1 dB/K) occurs at about 57 degree steering angle."). The variable G/T due to satellite pointing angle is caused by scan-loss effects on phased array antennas.
[62] *See Third Modification*, at Schedule S, 7-13, 15-24.
[63] *See id.* at Attachment A, 8 ("SpaceX will adjust power in order to achieve the PFD levels indicated above. The maximum EIRP density for all proposed altitudes is 12.7 dBW/MHz. For receiving beams, G/T will remain constant at 11.5 dB/K.").
[64] *See Second Modification*, at Schedule S, 31-48.
[65] *See Third Modification*, at Schedule S, 15-24.
[66] *See Second Modification*, at Schedule S, 9-20.
[67] *See Third Modification*, at Schedule S, 7-13.
[68] *See Second Modification*, at Schedule S, 9-20.
[69] *See Third Modification*, at Schedule S, 7-13.

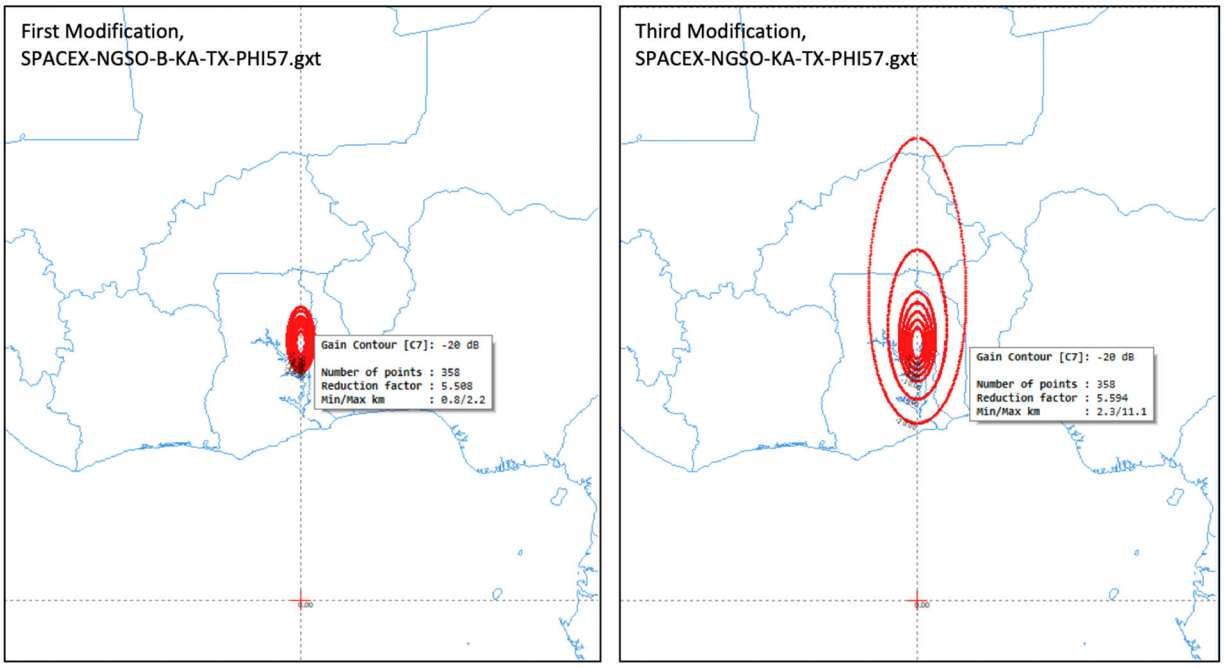
Minimum G/T (Rx)	dBK	11.1[70]	11.5[71]

Generally, higher-gain antennas have narrower main-lobes, such that the footprint projection covers less area than a lower-gain antenna. The size of a satellite's beam footprint has a significant effect on the interference environment, as Amazon described in its January 27, 2020 ex parte,[72] and as SpaceX has acknowledged in the context of other NGSO FSS applications.[73]

An inspection of the satellite beam contours submitted as part of the Schedule S for SpaceX's First Modification and Third Modification reveals a significant increase in contour area. This contradicts SpaceX's claim that "Operating these shells at lower altitude will significantly decrease each satellite's footprint on the Earth."[74] Figure 3 shows a satellite beam contour submitted with the First Modification (left), and a satellite beam contour submitted with the Third Modification (right), using the satellite and beam positions in SpaceX's GXT contour files. The satellite beam contours in the GXT files are displayed using the ITU Graphical Interference Management System (GIMS) software.[75]

[70] *See First Modification*, at Attachment A, 9.
[71] *See Third Modification*, at Attachment A, 8.
[72] *See* Letter from Mariah Dodson Shuman, Corporate Counsel, Kuiper Systems LLC, to Marlene H. Dortch, Secretary, FCC, at 5 (Jan. 27, 2020) ("Boeing's large spot beams would have been much more difficult to isolate from earth stations on the ground than smaller spot beams and would have substantially complicated interference avoidance and resolution. By comparison, the small and compact spot beams in the Kuiper System reduce the potential for in-line events and create new options for sharing among NGSO systems.").
[73] *See* Consolidated Reply of Space Exploration Holdings LLC, IBFS File Nos. SAT-LOA-20161115-00117 et al, at 3-4 (filed July 14, 2017) ("[T]his argument glosses over the fact that large beams covering earth stations in a large area for relatively long periods experience more in-line events than do smaller beams.").
[74] *See Third Modification*, at Attachment A, 4.
[75] To ensure an apples-to-apples comparison, a common satellite pointing angle of 57 degrees from nadir was used in both contours below, which translates to a 25-degree earth station elevation. The currently authorized 40-degree earth station elevation contours from SpaceX's previous applications would be smaller than those shown on the left side of Figure 3.

Figure 3: Satellite Beam Contours Submitted with First versus Third Modification



Left: First Modification, Ka-Band Transmit, Phi=57 degrees, Elevation=25 degrees. Right: Third Modification, Ka-Band Transmit, Phi=57 degrees, Elevation=25 degrees. Outer contours both represent Peak Gain - 20 dB.

The authorized satellite beam contour (Figure 3, left) covers approximately 20,000 km^2 of land area. The satellite beam contour in the Third Modification (Figure 3, right) covers approximately 300,000 km^2. The satellite beam contours above only show the beam projections from a single satellite position, which does not capture the full effect of the increased footprints. To understand how the increased interference footprint size truly affects the NGSO FSS interference environment, the envelope of footprints from all possible SpaceX satellite positions in view must be considered. This is shown below in Figure 4 with the -20 dB satellite beam contour[76] envelopes shown for the First Modification (1325 km satellite altitude: blue dotted line, 550 km satellite altitude: green solid line) and Third Modification (540 km satellite altitude: orange

[76] The contours included in SpaceX's Schedule S databases are limited to -20 dB from peak.

dashed line). The full envelopes of the currently authorized and Third Modification -20 dB satellite beam contours, swept over all azimuth directions from which they could be received, are shown on the right diagram in Figure 4. The Third Modification satellite beam contour (orange dashed line) covers over 50x as much land area as the currently authorized contour for satellites at 1325 km altitude (blue dotted line), and covers over 150x as much land as the currently authorized contour for satellites at 550 km altitude (green solid line).

Figure 4: Satellite Beam Contours, Single Satellite Position and Possible Satellite Positions

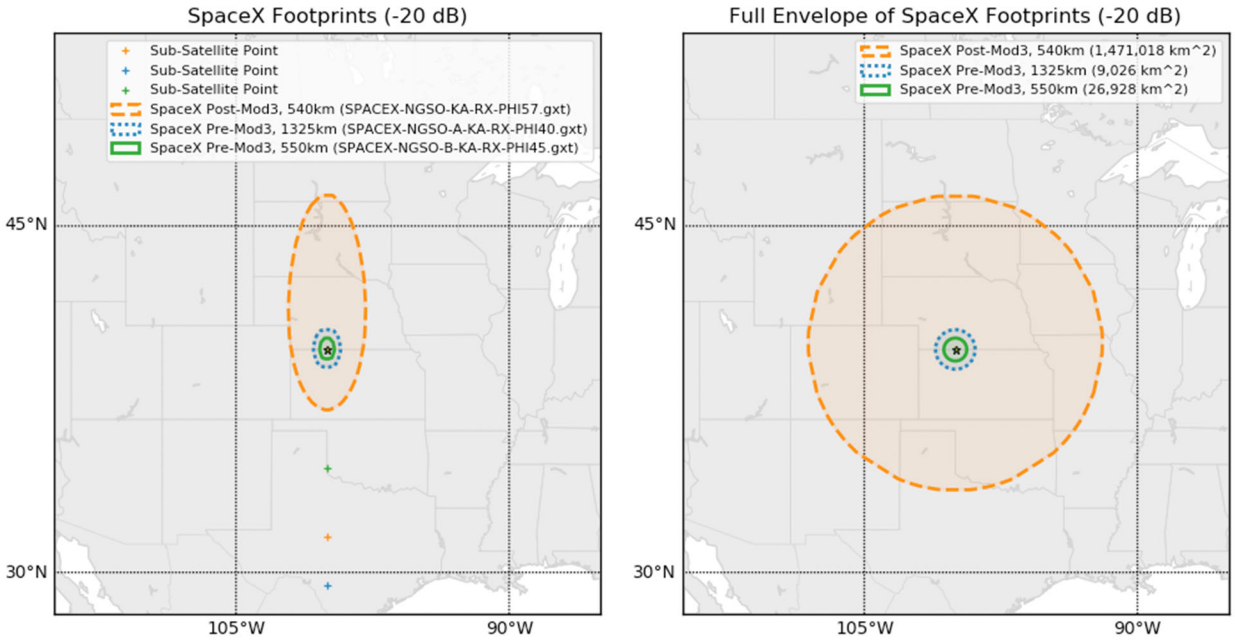
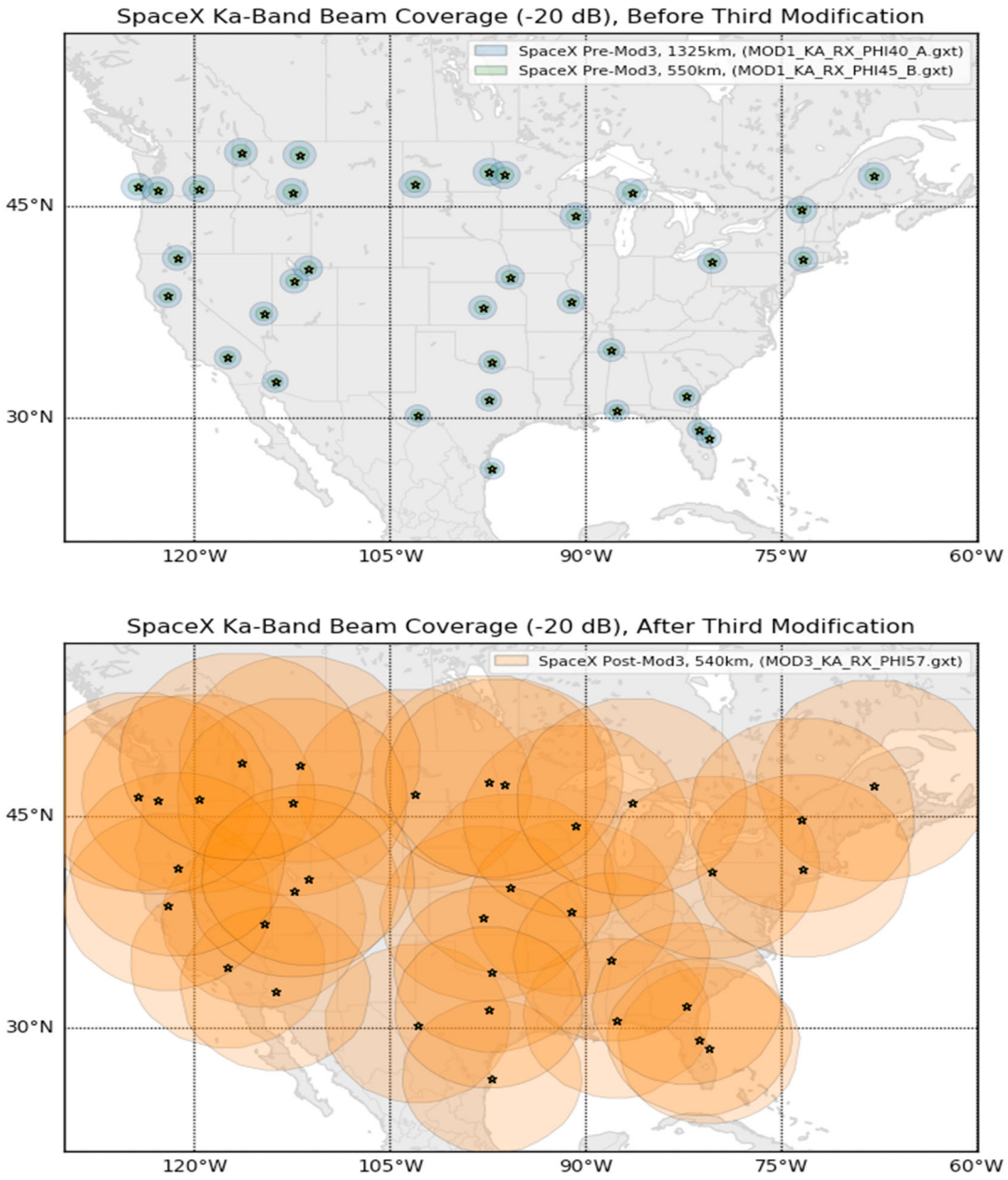


Figure 5 below shows the full envelope footprints from all SpaceX satellite positions with respect to Ka-band earth stations for which SpaceX has applied for in the United States. The impact is profound. SpaceX's proposed -20 dB satellite beam contours cover virtually the entire continental United States, essentially eliminating geographic separation between Ka-band earth stations as a sharing mechanism whether or not SpaceX has an earth station in a particular location. This broad expansion of SpaceX's beam coverage would impact both GSO and NGSO FSS Ka-band earth stations and significantly alter the NGSO interference environment, dramatically

reducing the interference mitigation remedy previously possible by earth station separation and advantage SpaceX to the detriment of other Ka-band satellite operators.

Figure 5: Satellite Beam Contours at Select Requested Earth Station Locations, Before and After Third Modification

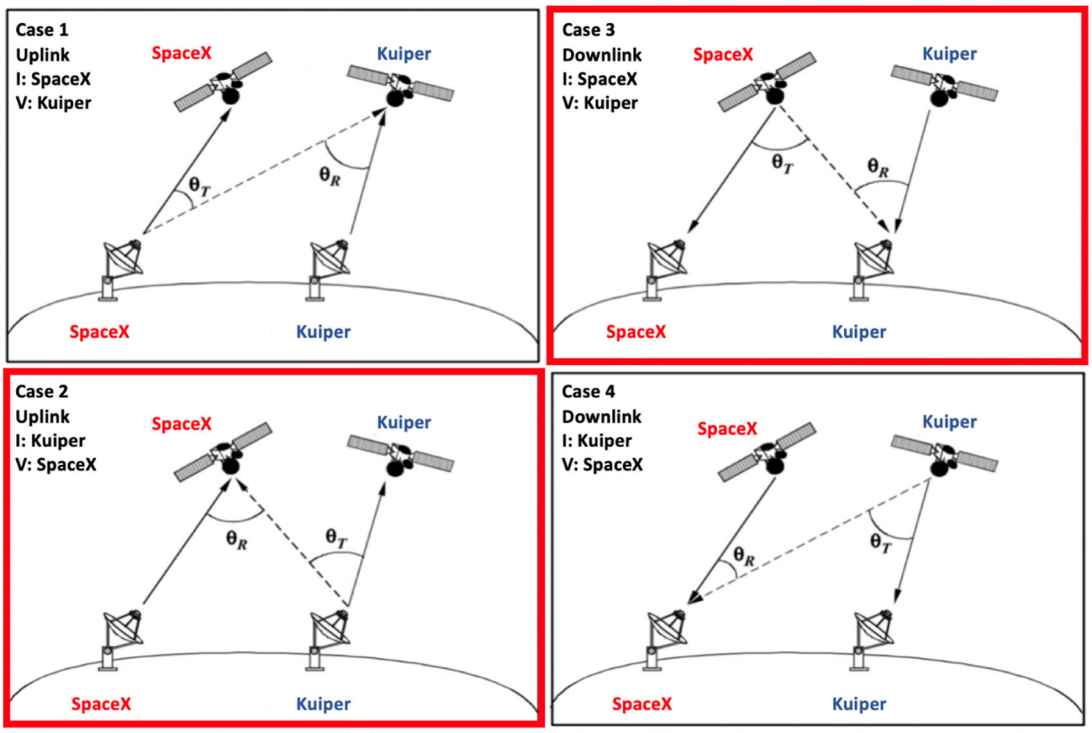


In NGSO FSS / NGSO FSS interference scenarios, there is a natural trade-off between the separation angle at the victim receiver and the separation angle at the interferer transmitter. If earth stations from two networks are sufficiently separated, geographical separation can offset the

interference between them. The distance required to offset interference is determined by each satellite system's beam footprints. The increase in SpaceX's Ka-band satellite beam contour coverage area significantly worsens Cases 2 and 3 shown in Figure 6. In the uplink direction, SpaceX satellites will have higher off-axis receive gain, thereby increasing their received I/N from other systems' earth stations. In the downlink direction, SpaceX reduced its peak PFD to partially mitigate the increased interference that the Third Modification causes.[77] Even with SpaceX's PFD reduction, other systems' earth stations will receive higher PFD levels from SpaceX's off-axis transmissions due to the modified SpaceX satellite beam contours. For example, using SpaceX's currently authorized satellite transmit beam contours, a Kuiper System earth station can expect to receive a PFD level under -136.3 dBW/m^2/MHz from SpaceX satellites if the Kuiper System earth station is 140 km from a SpaceX gateway earth station. Using the transmit beam contours from the Third Modification, the Kuiper System earth station would have to be at least 280 km from a SpaceX gateway earth station to experience a PFD level under -136.3 dBW/m^2/MHz. This problem is aggravated further at lower PFD levels as the currently authorized and modified beam patterns diverge further.

[77] *See Third Modification*, at Attachment A, 9-10.

Figure 6: NGSO-NGSO Interference Scenarios



SpaceX provided an insufficient response to Amazon's demonstration that the Third Modification worsens the NGSO FSS interference environment and impacts the Kuiper System. Amazon's Petition showed that this modification significantly exacerbates the interference in Cases 1, 2, and 3 shown in Figure 6, and worsens the interference for some percentages of time in Case 4. Contrary to the position it took in other filings, SpaceX claimed that earth station separation could resolve the interference between the two systems' gateway links.[78] However, the

[78] *SpaceX Opposition*, at Appendix A, A-6-A-7 ("Given the fairly limited number of gateways to be deployed by each operator, [co-location] is too implausible to support a reasonable interference analysis and, in any event, could readily be avoided by both operators."). Yet, SpaceX previously claimed that earth stations would generally be co-located. *See* Letter from David Goldman, Director of Satellite Policy, SpaceX, to Marlene H. Dortch, Secretary, FCC, at 5 (Feb. 20, 2020) ("Amazon incorrectly claims that earth stations from multiple systems will not generally be co-located. . . . [L]arge systems like the one Amazon is planning will often need to co-locate gateway earth stations with those from other systems."). SpaceX has also used similar co-location assumptions in interference analyses and explanations in response to petitions against its own First Modification, *see* Further Consolidated Opposition to Petitions and Response to Comments of

very interference mitigation technique SpaceX proposes would be made ineffective with SpaceX's requested expansion of its satellite beam footprints. The increased interference caused by SpaceX's modified satellite beam contours would impact the ability to re-use spectrum among NGSO FSS Ka-band systems in the United States by weakening a key interference mitigation technique.

3. Statistical I/N analysis does not convey the full effects of the Third Modification.

The impacts of the Third Modification cannot be reduced to a single I/N cumulative distribution function chart for one of many interference scenarios, as SpaceX produced with respect to the Kuiper System.[79] Each of SpaceX's modifications will result in unique operational impact to other NGSO FSS systems, such as the presence of in-line interference events at low elevation angles and reduced satellite availability.

Amazon demonstrated that the Third Modification causes a significant percentage increase in the number of in-line interference events experienced by Kuiper System satellites as well as a significant percentage increase to the SpaceX system's susceptibility to interference. SpaceX observed that the increase in the percentage of time that Kuiper System satellites are affected by in-line interference events was higher than the increase in the percentage of time that SpaceX downlinks are affected by any given I/N.[80] Amazon demonstrated that the percentage of time that SpaceX downlinks would experience I/N levels greater than -12.2 dB would increase by 61% due

Space Exploration Holdings, LLC, IBFS File No. SAT-MOD-20181108-00083, Attachment A, A-1 (filed Feb. 21, 2019), and in comments against another NGSO FSS system application, *see* Comments of Space Exploration Technologies Corp., IBFS File No. SAT-PDR-20161115-00120 (filed June 26, 2017) (illustrating an in-line scenario using "essentially collocated" earth stations).

[79] *See SpaceX Opposition*, at Appendix A, A-7.

[80] *See id.* at 27 ("Amazon and OneWeb make a similar argument, concluding that the modification would increase the number and duration of in-line events (even though their graphs of downlink interference before and after the modification show only modest differences in the probability of interference at any given I/N value).").

to the changes in the Third Modification,[81] and the amount of time that Kuiper System satellites would experience in-line interference events would increase by between 113% and 308%, depending on the earth station latitude and exact in-line interference event angular threshold.[82] Both of these increases are significant and show that the Third Modification worsens the NGSO interference environment, but the percentage of SpaceX satellites affected by the Third Modification is less than the percentage of Kuiper System satellites affected because SpaceX has doubled the number of its satellites communicating with each earth station.

A simple example of this phenomenon: If an interference event occurred between one Kuiper System satellite and one SpaceX satellite using the authorized SpaceX system parameters, then 25% of the active Kuiper System satellites (1 of 4) would be affected and 25% (1 of 4) of the active SpaceX satellites would be affected. Using the modified SpaceX system parameters, if interference events occurred between three Kuiper System satellites and three SpaceX satellites, then 75% of the active Kuiper System satellites (3 of 4) would be affected and 37.5% (3 of 8) of the active SpaceX satellites would be affected. Comparing the percentage values to each other, this would be a 200% increase in the percentage of Kuiper System satellites affected, (75% - 25%) / 25%, but only a 50% increase in the effect on SpaceX satellites, (37.5% - 25%) / 25%. The impact of the Third Modification should be measured in how the unmodified systems are affected, i.e., the 200% increase in the percentage of Kuiper System satellites affected.[83]

The above example demonstrates how relying solely on statistical I/N analyses can be overly reductionist and does not accurately convey the full impact of the Third Modification on

[81] *See Amazon Petition*, at 23, Fig. 10.
[82] *See id.* at 19, Fig. 7.
[83] Each analysis discussed in the Amazon Petition to Deny was conducted by collecting millions of samples. The example above represents a single point in time in these analyses.

the NGSO FSS interference environment. SpaceX proposes that it will accept additional interference by simply translating the time percentage at which an I/N interference threshold is achieved with its authorized system to a new I/N interference threshold for its modified system.[84] This method does not sufficiently characterize the change in the interference environment, nor does it mitigate the impact to other NGSO FSS systems. A condition to accept a certain amount of interference based on these results would be insufficient and unworkable,[85] and the broad impacts to the NGSO FSS interference environment require the redesigned SpaceX system to be included in the 2020 Processing Round.

4. SpaceX's analysis does not properly reflect the interference between SpaceX and the Kuiper System.

SpaceX's showing of the interference effect on the Kuiper System only considered a single interference scenario: the interference from a Kuiper customer terminal into SpaceX satellite receivers. The analysis reaches the incorrect conclusions that a) the Third Modification cannot worsen this interference scenario, and b) the interference in the uplink direction moots the worsening interference to downlinks.[86]

In its analysis of Kuiper System customer terminal uplink interference into SpaceX satellite receivers, SpaceX considered the worst possible combination of Kuiper System customer terminal earth stations and emission power density from Kuiper System ITU filings, and did not consider

[84] *See SpaceX Opposition*, at Appendix A, A-2 ("As stated in this filing, although the proposed modification causes an increase in interference to SpaceX's uplinks, SpaceX is willing to accept this additional interference. For example, in this case, the point at which the curve for the currently authorized system crosses -12.2 dB I/N is at the same point on the vertical axis as the point at which the curve for the modified constellation crosses -9.6 dB. Accordingly, we will assume an in-line event trigger of I/N = -9.6 dB for OneWeb's interference into SpaceX uplinks, thus maintaining the same 8% probability of interference to SpaceX uplinks as modified, without additional protections.").

[85] *Id.*

[86] *Id.* at Appendix A, A-7.

other Kuiper customer terminal types as well as interference mitigation options, including power reductions.[87] There are a host of techniques that satellite systems may use to mitigate interference through the coordination process. Interference between the systems is not immutable, which means that the interference can be and is made worse by the Third Modification.

SpaceX claims that when there is interference from Kuiper System uplinks into SpaceX uplinks (Figure 6, Case 2), then potential interference from SpaceX downlinks into Kuiper System downlinks (Figure 6, Case 3) is "entirely theoretical."[88] SpaceX appears to think this obviates the need to address interference from SpaceX downlinks into Kuiper downlinks (Figure 6, Case 3). However, interference scenarios are often independent, and uplink and downlink interference can be avoided or resolved independently using different interference mitigation techniques. For example, a reduction in power on one link can resolve interference in one direction without affecting links in the other direction. Likewise, spectrum overlap may occur in one link direction and not the other. This is a common occurrence, as uplink and downlink bandwidth requirements are often asymmetrical, especially in broadband applications. For these reasons, the Third Modification's effect on each interference scenario as well as its impact to other systems must be considered independently, which SpaceX did not do.

As the above analysis shows, the Third Modification's effect on the RF environment is not comparable to those of the First Modification and Second Modification because the Third Modification involves redesign of both the constellation and the satellites. SpaceX attempts to justify its proposal by citing to the Commission's decisions in those two previous grants, stating

[87] While it is sometimes appropriate to consider a bounding case of interference between two systems, it is illogical to assume this represents 100% of the potential interference between the systems.
[88] *Id.* at Appendix A, A-7.

that it "is taking a number of steps that the Commission has recognized—including when approving SpaceX's first, similar modification—as factors that demonstrate that a modification will not meaningfully increase interference to other NGSO systems. . . . Each of these features alone could reduce the potential for interference."[89] However, as shown by Amazon and other commenters, the Third Modification does not reduce the potential for interference. Like its effect on space safety,[90] the Third Modification's significant parameter redesign would have a serious, deleterious effect on the interference environment that differentiates it from the First and Second Modifications and requires consideration, if at all, in the 2020 Processing Round.

IV. CONCLUSION.

The record in this proceeding establishes that there are significant, unresolved space safety and interference issues created by the Third Modification. This substantial redesign would undermine the Commission's policy goals underlying its use of NGSO FSS processing rounds, depriving other licensees of regulatory certainty and enabling serial modifications to continue.

SpaceX's proposed system redesign could increase the daily close approaches with the Kuiper System by more than an order of magnitude, yet SpaceX declines to acknowledge potential solutions. SpaceX has not addressed important concerns raised by commenters about the need for transparency regarding the reliability of its satellites. Additionally, the system redesign proposed in the Third Modification would significantly worsen the NGSO FSS interference environment for the Kuiper System and other operators in both the 2016 and 2020 processing rounds. SpaceX's analysis of the impacts to other NGSO FSS systems, including the Kuiper System, is incomplete, and SpaceX has not proposed a sufficient remedy to the significant interference issues commenters

[89] *Third Modification*, at 9-10.
[90] *See* Part II.A.

have demonstrated. The Third Modification presents significant interference problems and does not meet the *Teledesic* standard.

In conclusion, the Commission should deny the Third Modification based on the record in this proceeding. If the space safety risks warranting denial can be resolved, Amazon requests that the Commission include the entire modified SpaceX constellation as part of the 2020 Processing Round to ensure that the public interest is served.

Respectfully submitted,

Mariah Dodson Shuman

Mariah Dodson Shuman
Corporate Counsel

Kuiper Systems LLC,
an Amazon subsidiary
410 Terry Avenue N
Seattle, WA 98109

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CERTIFICATE OF SERVICE

I hereby certify that, on this 7th day of August 2020, a copy of the foregoing Reply was served upon:

William M. Wiltshire*
Paul Caritj*
Harris, Wiltshire & Grannis LLP
1919 M Street, NW, Suite 800
Washington, DC 20036

Patricia Cooper*
David Goldman*
Space Exploration Technologies Corp.
1155 F Street, NW, Suite 475
Washington, DC 20004

Counsel to Space Exploration Technologies Corp.

*Service via electronic mail due to COVID-19

/s/Leslie Gray
Leslie Gray